Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Dangerous Goods **4 July 2013**

Joint Meeting of the RID Committee of Experts and the Working Party on the Transport of Dangerous Goods

Geneva, 17-27 September 2013
Item 7 of the provisional agenda
Reports of informal working groups

Report of the informal working group on the reduction of the risk of a BLEVE - Annexes

Transmitted by the Government of the Netherlands on behalf of the working group

This informal document contains annexes 1-3 of the report contained in document ECE/TRANS/WP.15/AC.1/2013/61.

Annex 1

Annex to the report of the working group meeting in Berlin, April 2013 of the informal working group on BLEVE, Berlin, 15-17 April 2013 (see ECE/TRANS/WP.15/AC.1/2013/61)

Presentation by Germany/BAM on the results of the testing program on tanks with thermal coating and with pressure relief device (PRV)

The representative of Germany/BAM presents the results of the testing program. See annex 2 to the report with the presentation. One conclusion is that a PRV alone is not effective to reduce the time to BLEVE when a tank is in a fire engulfment. Another conclusion is that under the same condition an appropriate (type and thickness) coating can delay a BLEVE for one hour. And the conclusion about an appropriate coating in combination with a PRV is that it can delay a BLEVE for 1.5 hour.

Discussion about the testing results

The working group discussed the representativeness of the fire used in the test.

The testing conditions have already been presented in the testing report of the BAM 2010. It is a standardized test for a fire engulfment (pool fire). It can be reproduced. The test fire is neither a small fire nor an extreme accident condition. It is considered to be representative for a pool fire. A pool fire shows a fire temperatures between 900 °C and 1000 °C. In tunnels the fire temperature will even be higher. The testing fire of 75 kW/m^2 is a standardized condition for a pool fire.

In everyday life there are problems with tanks in a fire. The question is whether a fire is a circumstance during transport that needs to be taken account of.

The torch fire is not tested in the BAM testing program. A torch fire is considered to be a more severe fire than a pool fire. USA and Canada use different delay times for a BLEVE to resist a pool fire and a torch fire.

The working group discussed the PRV.

The tests show that several PRV's failed in a pool fire. PRV's are meant to release the pressure when a tank is overfilled and exposed to temperature increase (e.g. solar radiation). The purpose of a PRV is not to resist a fire and it is therefore not tested in that way. A defect PRV can release pressure continuously. The tests also show that the influence of a PRV on the time to delay a BLEVE is insufficient for emergency response, even if the PRV works properly.

Paragraphs 4.2.5.3, provision TP6, and 6.7.3.8.1 in ADR/RID claims that a PRV should enable a tank to resist a fire engulfment. The assumption in ADR/RID, that a PRV can avoid a BLEVE in the tank in fire conditions, is proven wrong by the tests. The reason for this malfunction, is that the fire weakens the steel of the tank, which leads to a BLEVE. A PRV cannot prevent a hot BLEVE, even though the texts of TP6 and 6.7.3.8.1 may give another impression. This finding shall be reported to the UN TDG Sub-Committee. The existing provision for PRV in the UN regulations should be evaluated.

PRVs on tanks have disadvantages: (Mal)functioning of a PRV gives a release of toxic or flammable gas. Release of a flammable gas by a PRV can result in a torch fire.

The working group discussed the thermal coating.

The BAM bonfire tests with a $3m^3$ tank prove that:

A PRV gives hardly no delay of hot BLEVE;

Only top coated tanks with PRV give very limited delay of a BLEVE;

A fully coated tank delays a BLEVE by one hour;

A fully coated tank with PRV delays a BLEVE by 1.5 hour.

The participants discussed these conclusions and in general accept the conclusions.

(The AEGPL accepted some of the conclusions but remained with concerns and questions in particular as the test report with the more detailed information had not been distributed.)

However the delegates and the BAM researchers still have some questions with respect to the testing programme and extrapolation of the conclusions to a real 40-110 m^3 RID/ADR conforming tank sizes.

Discussed uncertainties are:

Are BAM test fire conditions representative for a real scale tanker fire?

How can we prove that the BAM small scale storage standard tank and equipment test is relevant for a full scale RID/ADR tank?

What is the positive influence of one or more well designed PRVs for fire conditions on the time to BLEVE?

What are possible negative consequences of one or more PRVs (additional heat radiation from a flare) on the time to BLEVE?

What is the impact resistance of an overturning tank and tank collision, does it affect the time to BLEVE? (e.g. appearance of hot spots, additional risk to emergency services)

What is the life time performance (and manufacturer's warranty) of coated tank with respect to vibrations, degradation and corrosion?

Is the required ADR/RID inspection and maintenance of coated tanks and use of NDT methods possible?

The working group discussed the societal en political aspects of a coating to prevent a BLEVE.

The effectiveness of a coating to prevent a hot BLEVE does not mean this measure is also necessary. The necessity of the measure depends on a risk assessment and on risk acceptance criteria. But several countries already experienced low acceptance of risk by the public when it concerns the transport of dangerous goods. Preventive evacuations of the public in accident conditions may lead to serious opposition to the transport of dangerous goods and a call for restrictions of transport or other measures. In the Netherlands and in France the probability of a BLEVE is not considered so low, that it is irrelevant to take measures. It is important to know that a coating is effective to delay the time to BLEVE when a tank with flammable gas is on fire. A coating can provide time for the fire brigade to extinguish the fire and prevent/delay a BLEVE. The costs and the other disadvantages of a coating are also relevant, but should be examined if they could be acceptable if taken on a large scale.

A question that has to be answered is whether a fire is a circumstance during transport that needs to be taken account of. This question is for the Joint Meeting and cannot be answered by this working group.

The working group discussed on the combination coating and PRV.

The effect of a coating in combination with a PRV on the rise of the temperature of the tank is better than the effect of a coating alone. But a PRV can lead to a torch fire and cause a domino effect in accident conditions. Is it not expected that a BLEVE can be prevented altogether, without extinguishing the fire, because the thermal epoxy desintegrates slowly, after 1.5 hour external fire exposure the coating gives no protection anymore and the remaining gas in the tank can still lead to a BLEVE.

The working group discussed on the report of the tests.

The full report of the tests by BAM can give more information about specific questions raised in the working group. The report has not yet been send to the participants of the working group. Germany/BAM will send the report to the participants of the working group soon. The report of 2010 that has been sent previously to the participants, will be sent again.

The working group discussed the need for further full scale testing.

The testing results with small storage standard tanks and PRVs (compared to RID/ADR standards) do not prove the coatings will give the same results on a full scale RID/ADR transport tank. Therefore it seems that one or more full scale test(s) is needed for final conclusions on PRVs and coatings. Some alternatives are discussed, for instance to ask for the results of tests by others. The existing information however is that a full scale test has not been done elsewhere. Another alternative is to do a coated plate test in a furnace, combined with calculations on the effect on the wall temperature and the resistance against fire. The qualification of the coating material can be defined by calculations. The Netherlands already tested a 3 m^3 coated tank, the results of the test were published in the Journal of Hazardous Materials[1]. This test confirmed the results of the calculations, the coating prevented a BLEVE for more than an hour.

The working group discussed further questions to be answered.

See annex 3 to this report.

The Netherlands feels there is a need for a summary on the available scientific knowledge on the subject of coatings and PRVs that can answer several interesting questions by this working group and others. The Netherlands offers to provide for such a summary by the end of this year to help with the discussion.

Work proceeding

Conclusions on how to proceed on the subject of coatings and PRVs

Germany will send the report of 2010 tests and more details on the 2011-2012 tests as requested by all participants, as soon as possible.

Germany will present the results of the testing program in the Joint Meeting.

The Chairman will communicate the findings of the working group about PRV regulations in ADR (paragraphs 4.2.5.3, provision TP6, and 6.7.3.8.1) to the UN TDG Sub-Committee.

Answers to the open questions mentioned in annexes 2 and 3 to the report.

The Netherlands will present a scientific state of the art review with respect to the questions on uncertainties and extrapolation of the conclusions to real tank size by the end of 2013 and to be discussed in a following meeting of the working group.

[1] Landuccia G., Molag M. et.al.; Journal of Hazardous Materials, 2008 May 1.

The representative of AEGPL reminded the working group that the mandate and scope of the working group is broader than investigating the measures thermal coating and PRVs.

Next meeting

The next meeting of the working group will be planned after the next Joint Meeting in September 2013.

Annex 2

Joint meeting – Bleve Working Group (BAM (15 – 17 April 2013, Berlin)

Federal Institute for Materials Research and Testing

JOINT MEETING – BLEVE WORKING GROUP

BAM (15. – 17. APRIL 2013 BERLIN)

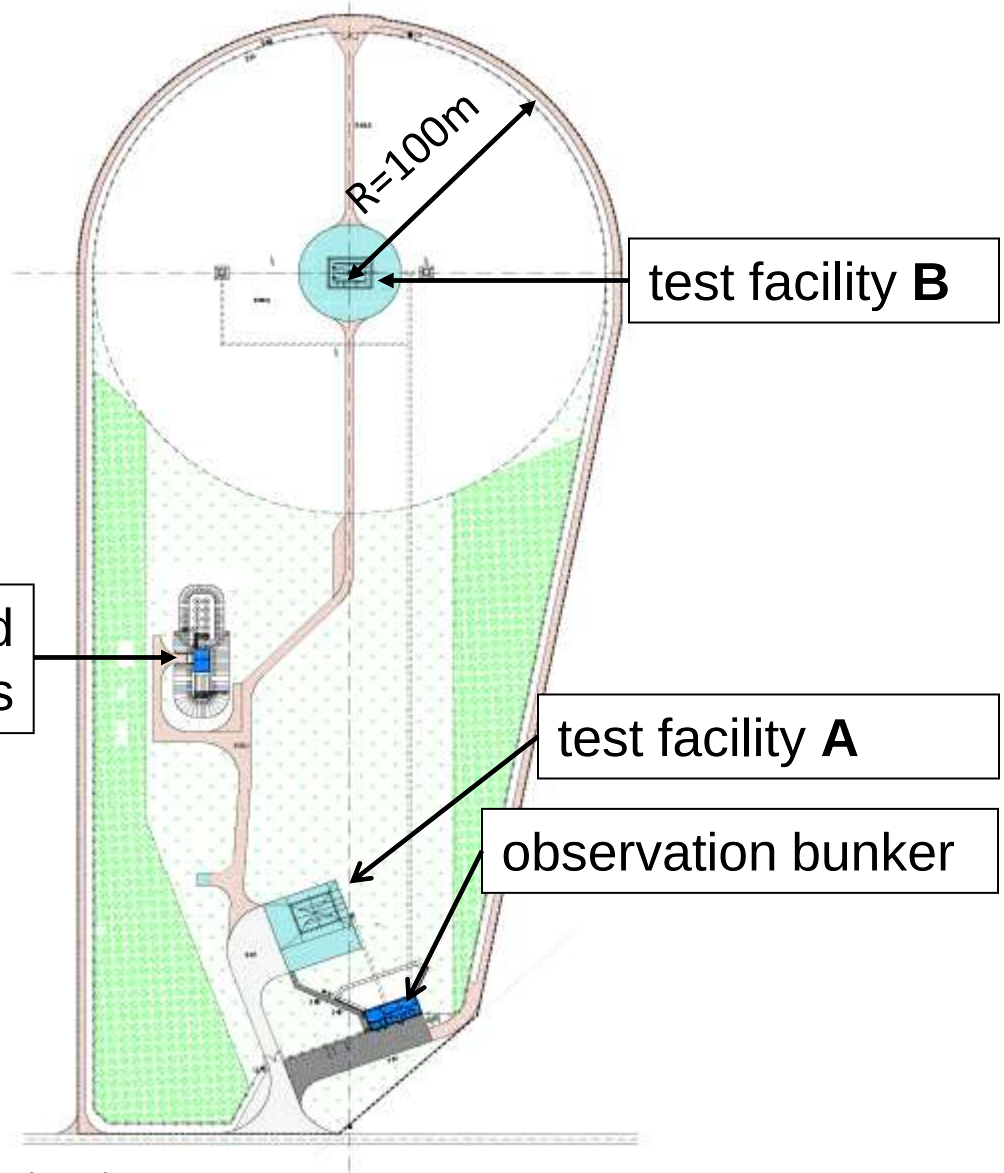
Ch. Balke, F. Otremba, Ch. Sklorz

Distribution

- BAM Test Site Technical Safety (TTS)
- Tank fire tests
- Results of different tank configurations
- Limit load test and analysis in FEM
- Conclusion

BAM Test Site Technical Safety (TTS)

- ca. 50 km south of Berlin
- 12 km² Area
- different large test facilities



- **map of the area**
- *Fire test facility on the Test Site Technical Safety (TTS)*

Test facility A for non destructive tests

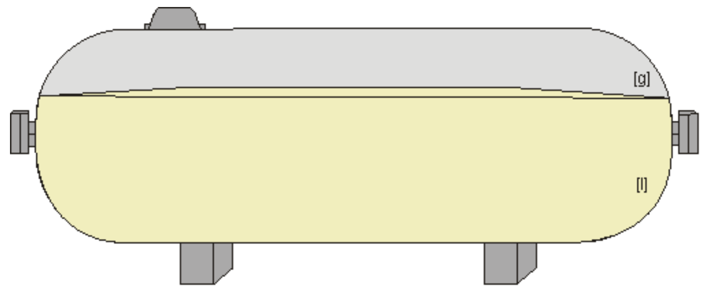
- Heat source: liquid propane
  (UN 1965 Mixture C)
- Surface: 12 m X 8 m
- Heat load: up to 110 kW/m²
- Sheet metal as protection against wind
- Max. mass for test objects 200 t
- Flexible ring-burner, water cooled

Test facility B for destructive tests

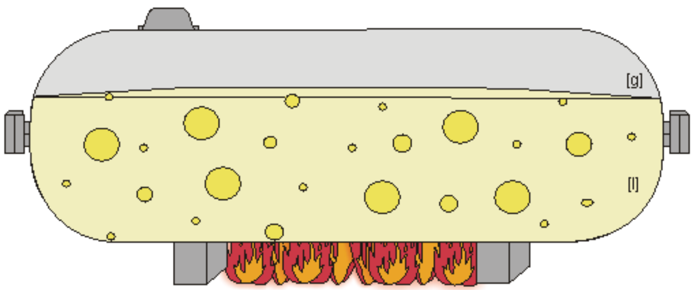
- Heat source: liquid propane
- Surface: 12 m X 8 m
- Heat load: up to 110 kW/m²
- Concrete with steel plates as protection against wind or parts in case of explosion
- Max. mass for test objects 20 t, for vehicles 40 t
- 416 individual nozzles in 26 lines for the reduction or extension of fire surface or heat load

Process of motivating

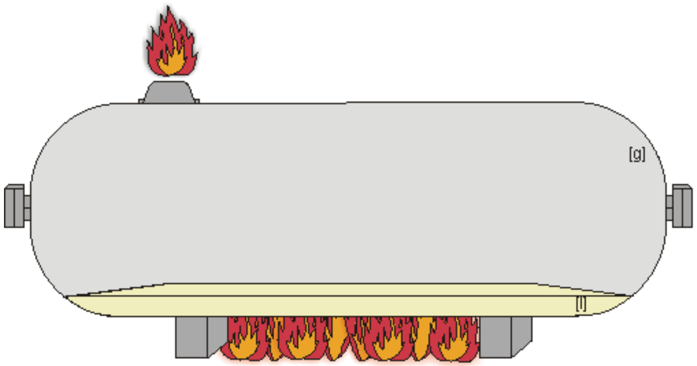
Development of a BLEVE



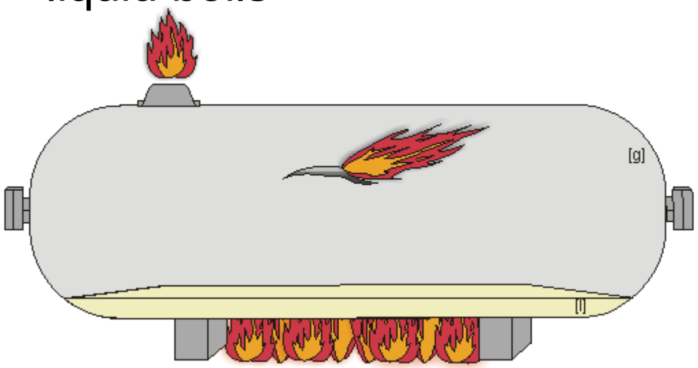
- filled tank



- tank is located in fire
- liquid boils



- pressure rises
- safety valve opens
- level of liquid drops



- pressure continues to rise
- tank wall weakens
- tank wall ruptures

Objectives

- heat input in accordance with IAEA ≥ 75 kW/m^2
- heat source: Pool – fire
- test tank completely enclosed by the fire
- duration in experiment fire 60 – 90 min

Overview of tank fire tests

Real scale investigation tank

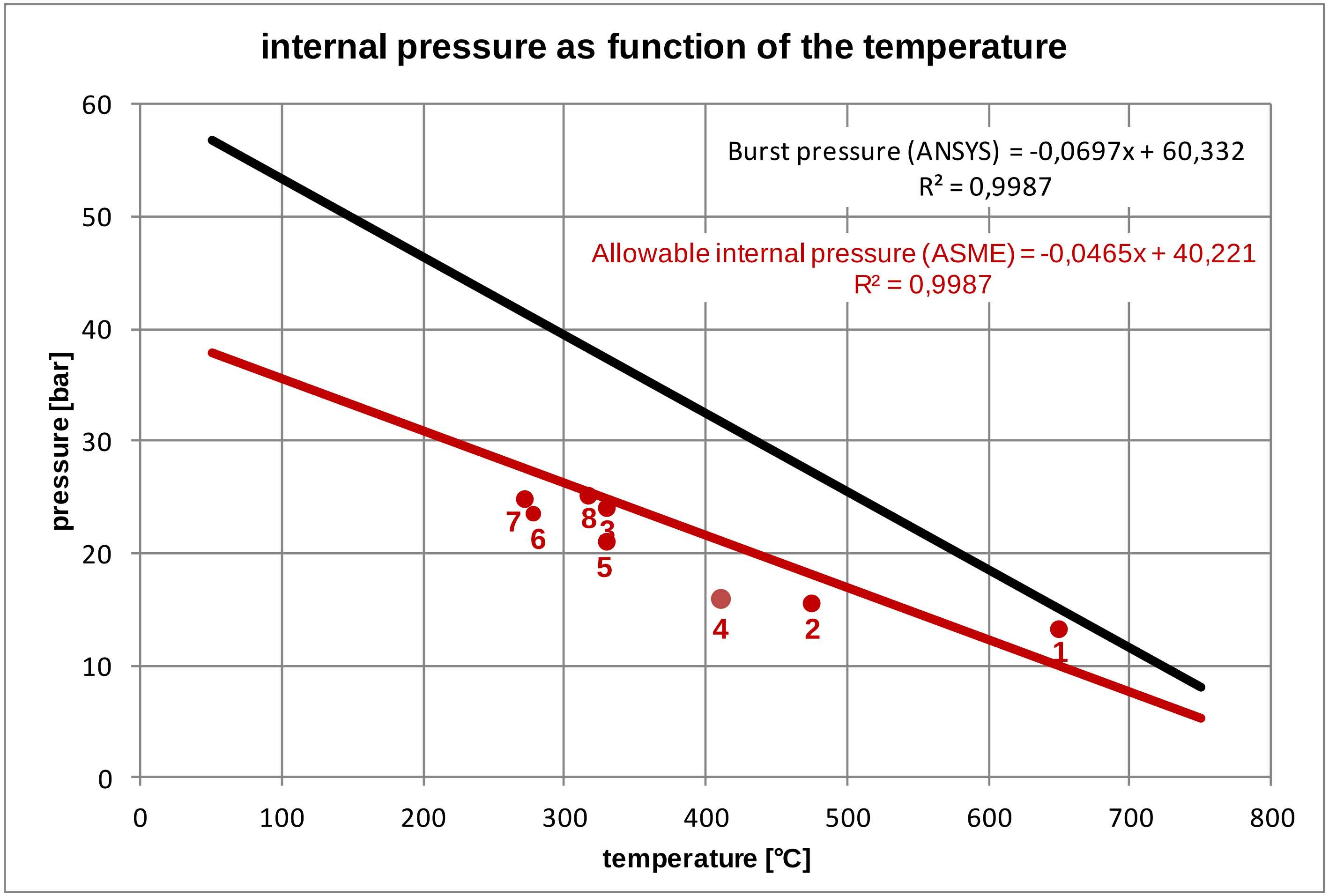
- 2,75 m³ tank, filled with 50 % propane
- **5 different groups are tested**
  - variation of the degree of coating (full and partly)
  - variation of the coating thickness (4 – 10 mm)
  - variation of coating manufactures (A, B, C, D, E)
  - variation of different coating procedures (spray and hand)
  - with and without PRV

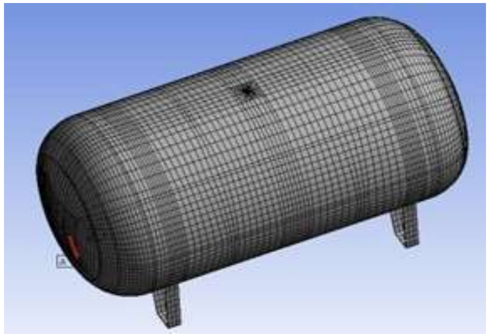
- internal pressure measurement
- temperature measurements (outside/inside)

Tank with PRV (BLEVE)

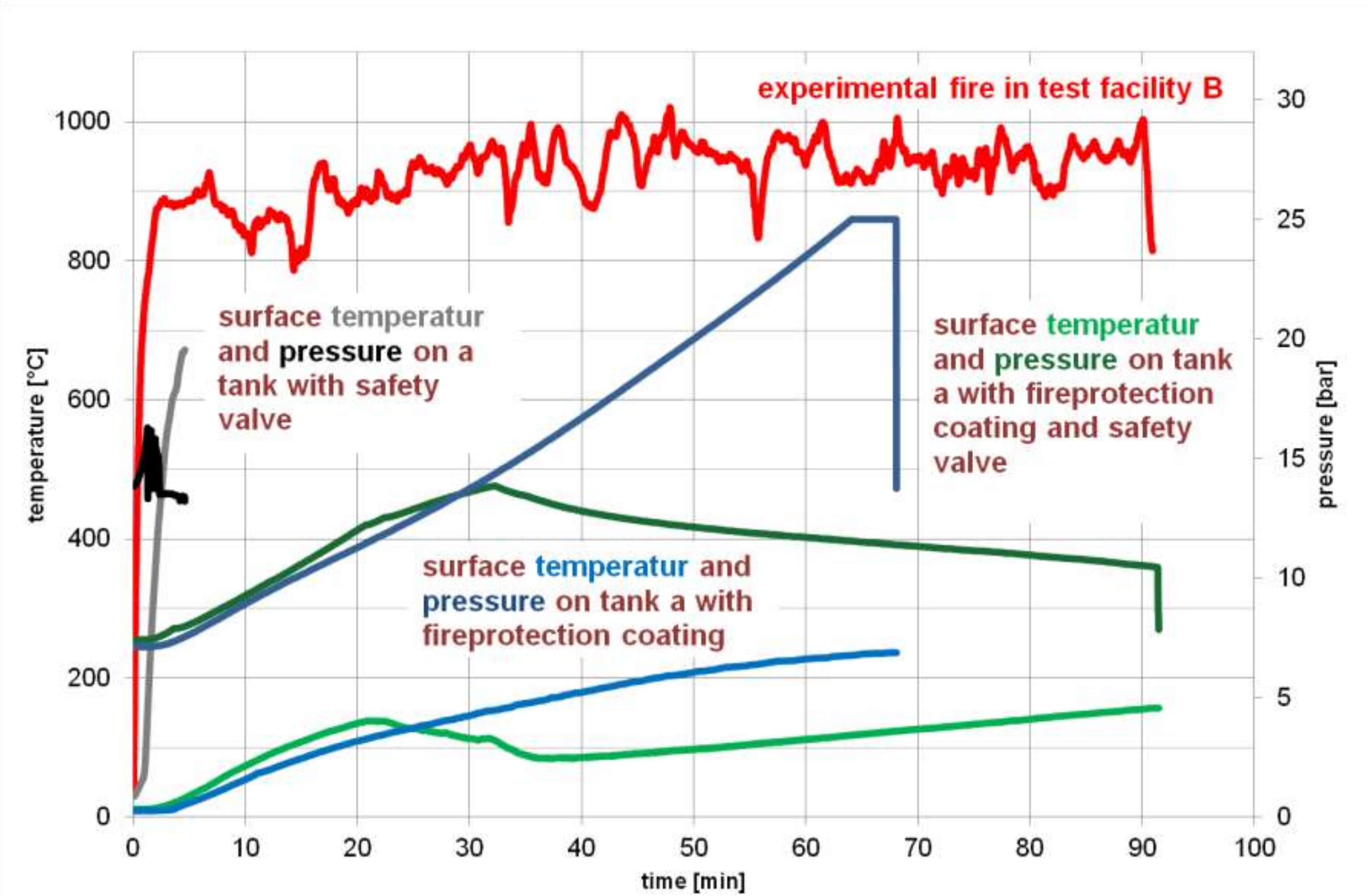
Tank with coating and PRV

criteria for all experiments: allowable pressure (2/3 limit load)
350°C wall temperature and/or 25 bar internal pressure





Results of different tank configurations



Different tank configurations

Tank configuration	PRV (size)	nominal thickness [mm]	max. Tank wall-temperature [°C]	max. internal pressure [bar]	fire protection coating [manufactures] [procedures]	Duration in experiment fire [min] interrupting criteria
	2"	-	650-750 on top	13,2	-	6 [BLEVE] (1)
	2,5" + 4bar rupture- disc	-	450	7,27	-	14 [rupture disc was activated]
			Filling = 10%; content = ethanol			
	1 ¼"	10	475 close-by PRV	15,5	[C] [Hand]	22 [Limit Load was achieved] (2)
	1"	6	330	24	[D] [Hand]	7 [Limit Load was achieved] (3)

Different tank configuration

	1"	8	410-450 Outside of the coating	16	[B] [Hand]	10 [Limit Load was achieved] (4)
	1"	3	short: 350 by stop: 215	16	[E] [Airless]	22 [coating replace]
	1"	8	300	13,4	[A] [Hand]	90 [lifetime achieve]
	1"	4	220	7	[A] [Airless]	8 [PRV failed]
	1"	6	229	12	[A] [Airless]	15 [PRV failed]
	-	10	330	21	[C] [Hand]	36 [Limit Load was achieved] (5)
	-	6	278	23,5	[D] [Hand]	28 [Limit Load was achieved] (6)
	-	10	272	24,8	[A] [Hand]	68 [Limit Load was achieved] (7)
	-	10	317	25,1	[B] [Hand]	55 [Limit Load was achieved] (8)

[C] = new coating material; coating thickness for this material not high enough

Conclusion

coating (100%)	PRV	durability
-	X	6 min
X	-	68 min
X	X	90 min

- coating is necessary to reduce wall temperature
- PRV can be helpful in addition with coating but it has to be protected
- variation of the coating thickness is possible

Questions are still open…

- mechanical impact (e.g. overturn, slips on road, low level falling…)
- influence of tank size (transferability from smal to real scale)
- qualification of the coating procedure (e.g. which coating can be used, art of application, minimum of thickness…)
- qualification of manworkship to achieve a unique level of quality
- resistance of coating (e.g. long term stability, handling, weather conditions.….)
- installation of a pre warning system relating to failure

  is it possible to realize?

Therefore it is necessary to develop codes and standards

Tank vehicle with coating

Thank you for your attention

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Annex 3

References :

- *Any liquefied product that could BLEVE*
- *Road tankers : 40 m3 up to 60m3*
- *Rail wagons : LPG up to 120 m3 PRV's ?*

Objective : to delay the BLEVE occurrence until at least 1 hour

1. Report from BAM:

- Tests made in 2010 (explanations, how, why, conclusions…)
- Last tests made in 2011-12 (explanations, how, why, conclusions…)

Action : to send these reports to the members of the RID-ADR Ad Hoc WG = BAM/BMVBS

Tests conditions & findings

Comments and pending items	**Further actions/clarifications**
2. Type of fire: • Pool fire only (total engulfment of the tank in the fire)? • This standard has been chosen according to the IAEA ≥ 75 kW/m²? • What about "jet fire" conditions? : o References to existing studies? o Further tests needed? Qualification procedure should be the same in all European Countries) • Other references available?	To get a better view and/or references on testing conditions
3. Type & size of tank: • Standard design reference • Larger scale test for final verification?	Pre-calculation? Model to be studied to transfer tests results from small (3 m^3) to bigger tank (40/60 m3 for road up to 120 m3 for rail)? Larger scale test?
4. Type & thickness of coating (Technical specifications): • Comments on the first findings from the last tests: o Thermal coating can delay the timing of BLEVE o Necessary to have 100% coating (not partially) • Manufacturer (type of coating: effectiveness / thickness / costs/ … o Transposition to bigger tank? • Inspection and maintenance issues	Other pending issues: • Mechanical impact (e.g. overturn, slips on road, low level falling…): what happens if part of the coating is removed? • Qualification of the coating procedure (e.g. which coating can be used, art of application, minimum of thickness…) • Resistance of coating (e.g. long term stability, handling, weather conditions…..) • Check the effectiveness of the coating in time

References :

- *Any liquefied product that could BLEVE*
- *Road tankers : 40 m3 up to 60m3*
- *Rail wagons : LPG up to 120 m3 PRV's ?*

Objective : to delay the BLEVE occurrence until at least 1 hour

- Transferability from small to real" scale :
  - Large scale test for final verification

5. Type & size of PRV's (Technical specifications):

- PRV alone, used in the tests, is not enough to withstand pressure increase for a long time:
  - What was the reason of failure (heat around the valve, design for static tank ? ...)
  - What about other type of PRV?
  - ….
- Size of PRV's?
- Number of PRV's?
- Working condition under fire?
- ….

- Weight/m2?

- Design of PRV's (to be check for use in fire condition)
- Share some views about the current requirements set out in special tanks provisions TP6, that already requires PRV's should be installed in such a way to avoid rupture of the shell in case of fire engulfment and how is done that in practice.

Therefore it is necessary to develop codes and standards